SHIFT2RAIL JOINT UNDERTAKING

DECISION ON THE ADOPTION OF THE SHIFT2RAIL MASTER PLAN

N°4/2015

THE GOVERNING BOARD OF THE SHIFT2RAIL JOINT UNDERTAKING,

Having regard to Council Regulation (EU) No 642/2014 of 16 June 2014 establishing the Shift2Rail Joint Undertaking (hereinafter "S2R Regulation")[1], and in particular Article 2(1)(c) of this Regulation,

Whereas:

(1) In accordance with Article 1 of the S2R Regulation, the Shift2Rail Joint Undertaking ("S2R JU") should establish, develop and ensure the effective and efficient implementation of a strategic Master Plan.

(2) In accordance with Article 4 of Annex I to the S2R Regulation, this strategic Master Plan should be a forward-looking document defining the priority research and innovation activities to drive innovation in the rail sector in the long term.

(3) In accordance with Article 4 of Annex I to the S2R Regulation, the Governing Board of the S2R JU approved the Master Plan on 24 September 2014. The Master Plan was then endorsed by the Council[2] on 10 February 2015.

At its meeting of 31 March 2015, has adopted the following decision:

Article 1

The Shift2Rail strategic Master Plan annexed to this decision is hereby adopted.

Done at Brussels, 31 March 2015

João AGUIAR MACHADO
The Chairperson

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[1] OJ L 177, 17.6.2014, p. 9.

[2] OJ L 36, 12.2.2015, p. 7.

SHIFT2RAIL STRATEGIC MASTER PLAN

Version 1.0

31 March 2015

The present document has been developed by the Commission services in close cooperation with the 8 Shift2Rail founding members other than the Union. These members are those that are listed in Annex II to the Council Regulation (EU) No 642/2014 of 16 June 2014 establishing the Shift2Rail Joint Undertaking ('S2R Regulation'), namely rail equipment manufacturers Alstom, Ansaldo STS, Bombardier, Construcciones y Auxiliar de Ferrocarriles (CAF), Siemens and Thales as well as infrastructure managers Network Rail and Trafikverket.

The present document also integrates comments received from stakeholders during numerous individual meetings with sector representatives and a public consultation meeting held on 20 June 2014, to which close to 200 stakeholders took part.

The present document represents the first version of the Strategic Master Plan of the Shift2Rail Joint Undertaking, as adopted by the Governing Board of the Shift2Rail Joint Undertaking by decision of 31 March 2015, following its endorsement by the Council on 10 February 2015. It shall serve a reference document for the call for associated members that will be launched by the Commission in accordance with Article 4(2) of the Statutes contained in Annex I to the S2R Regulation ('S2R Statutes').

The Master Plan is a living document that may be updated by the Governing Board of the S2R Joint Undertaking once the associated members have been selected and the Governing Board of the S2R Joint Undertaking reaches its full composition (i.e. including representatives of selected associated members as foreseen in Article 6 of the S2R Statutes).

SHIFT2RAIL MASTER PLAN

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1 Introduction

1.1 General policy context

1.1.1 A vision for European transport

The European Commission is committed to a Europe 2020 strategy based on smart, sustainable and inclusive growth. This includes achieving a more competitive and resource-efficient European transport system with a view to addressing major societal issues such as rising traffic demand, congestion, security of energy supply and climate change.

To achieve this, the Commission's 2011 Transport White Paper ("Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system") sets out a number of key goals to strengthen the role of rail in the transport system, given rail's inherent advantages in terms of environmental performance, land use, energy consumption and safety.

A number of these goals relate specifically to rail passenger and rail freight transport, while others relate more generally to urban mobility, with an indirect impact on rail.

Transport White Paper goals related to rail

For passenger rail

- *Triple the length of the existing high-speed rail network by 2030 so that, by 2050 the majority of medium-distance passenger transport should go by rail and high-speed rail should outpace the increase in aviation for journeys up to 1000 km;*
- *By 2050, connect all core network airports to the rail network, preferably high-speed;*
- *By 2020, establish the framework for a European multimodal transport information, management and payment system.*

For freight:

- *30% of road freight over 300 km should shift to other modes such as rail or waterborne transport by 2030, and more than 50% by 2050;*
- *Rail freight should be almost doubled – +360 billion ton-km (+87%) compared to 2005;*
- *Deployment of ERTMS on the European Core Network by 2030;*
- *By 2050, connect all seaports to the rail freight system;*
- *Rail Freight Corridors as the backbone of the EU freight transport system.*

For urban mobility:

- *Halve the use of 'conventionally-fuelled' cars in urban transport by 2030; phase them out in cities by 2050;*
- *Achieve essentially CO_2-free city logistics in major urban centres by 2030;*
- *By 2020, establish the framework for a European multimodal transport information, management and payment system.*

1.1.2 Creating the Single European Rail Area

The 2011 White Paper points out that the creation of a Single European Railway Area (SERA) will be crucial to achieving a modal shift from road towards more sustainable modes of transport such as rail, as this could serve to dramatically cut the costs of running passenger and freight trains by providing a common framework of rules and regulations for rail operators in all EU countries.

Since the adoption of the 2011 White Paper, a lot of progress has been made towards the goal of creating a Single European Railway Area. The agreement on the rail recast[1] will considerably change the way the rail market works, stimulating investment, improving market access conditions and strengthening the role of national rail regulators.

The recast also paved the way for the various major proposals that together form the Fourth Railway Package[2], without which the European single market cannot be complete. The proposals were adopted by the Commission in January 2013 and aim to remove remaining administrative, technical and regulatory obstacles that are holding back the rail sector in terms of market opening and interoperability. These issues will be addressed by the different initiatives in three main domains:

- **Domestic passenger market opening –** opening domestic rail passenger markets to competition, including open access lines as well as the routes under Public Service Obligations;
- **Infrastructure governance -** ensuring that infrastructure managers perform a consistent set of functions that optimises the use of infrastructure capacity, and that its organisation guarantees non-discriminatory access to the infrastructure and rail related services**.**
- **Interoperability and safety -** removing remaining administrative and technical barriers, in particular by establishing a common approach to safety and interoperability rules to decrease administrative costs, to accelerate procedures, to increase economies of scale for railway undertakings and to avoid disguised discrimination.

This package should allow very large savings on both administrative and running costs for train manufacturers, operators and national regulators, while also helping new entrants into the marketplace, thereby enhancing the quality and efficiency of rail services.

1.1.2.1 The role of Horizon 2020 and Shift2Rail

The measures contained in the Fourth Railway Package will be crucial to realising the Single European Railway Area and promoting a modal shift. However, they will not be sufficient. The overarching goals of establishing an internal market for rail and of strengthening the competitiveness and attractiveness of the rail sector, while also sustaining the position of the European rail industry, will necessarily imply the emergence of innovative approaches in business models, services and products, throughout the whole rail value chain. This will, in turn, require a dramatic increase in research and innovation efforts.

[1] Directive 2012/34/EU of the European Parliament and of the Council of 21 November 2012 establishing a Single European Railway Area (recast)

[2] The Fourth Railway Package – Completing the single European railway area to foster European competitiveness and growth, COM (2013) 25 final

The EU's new programme for research and innovation (R&I), Horizon 2020 (H2020)[3], will run from 2014 to 2020 with an estimated total budget of EUR 77 billion, of which roughly EUR 6.339 million will go towards support to smart, green and integrated transport. Of this, EUR 450 million has been earmarked for rail research and innovation activities. This represents close to three times more than the EUR 155 million in Union funding than was available under the previous research framework programme (FP7), which ran from 2007 to 2013.

A key objective of H2020 is to improve the efficiency of EU funding and better address societal challenges by pooling together existing R&I efforts and expertise, namely through Public-Private Partnerships (PPPs) in the form of Joint Undertakings.

In line with this, the Shift2Rail Joint Undertaking (S2R JU) was established by Council Regulation (EU) No 642/2014 of 16 June 2014. The S2R JU is a public-private partnership, providing a platform for the actors of the European rail system to work together with a view to driving innovation in the years to come by implementing a comprehensive and co-ordinated research and innovation strategy.

The Founding Members of the Joint Undertaking are the European Union plus eight representatives of the rail industry, including rail equipment manufacturers Alstom, Ansaldo STS, Bombardier, Construcciones y Auxiliar de Ferrocarriles (CAF), Siemens and Thales as well as infrastructure managers Network Rail and Trafikverket. Next to these Founding Members, additional members of the Joint Undertaking (Associated Members) will be selected through an open call for membership. They may include representatives of Europe's rail system, including manufacturers of railway equipment, infrastructure managers, railway undertakings, metro, tram and light rail operators, and other rail-related companies, as well as SMEs, research organisations, universities and actors from outside the traditional rail sector.

1.1.2.2 The role of the Connecting Europe Facility (CEF)

The Connecting Europe Facility (CEF) is the EU's new programme for investing in EU infrastructure priorities in transport, energy and telecommunications (digital networks) with a view to completing the European single market and boosting Europe's competitiveness.

Under the Connecting Europe Facility (CEF), €26.25 billion will be made available from the EU's 2014-2020 budget to co-fund TEN-T projects in the EU Member States.

Eligible projects will include activities aimed at removing bottlenecks on transport routes and bridging missing links, in particular on cross-border connections, as well as those that contribute to the deployment of the European Rail Traffic Management System (ERTMS) on principal routes of rail freight corridors and that support rail interoperability.

The CEF will also serve to deploy new technologies and innovative transport solutions with a focus on decarbonisation, safety, sustainability, accessibility, multimodality, efficiency and improved operation and management of the network.

[3] Regulation of the European Parliament and of the Council establishing Horizon 2020-The Framework Programme for Research and Innovation (2014-2020), SEC(2011) 1427-Volume 1 and SEC(2011) 1428-Volume 1

Thus, the CEF also has the potential to bring an important contribution to the development of the single European railway market and the deployment of innovative rail solutions. Shift2Rail will seek to develop synergies with this facility to ensure that tested and validated solutions emanating from the activities of the Joint Undertaking can be taken up for funding under the CEF.

1.2 Key challenges of the European Rail Sector

The European rail sector faces a number of important challenges that constitute each for itself and even more together serious barriers for the development of rail as a transport mode and for the maintenance and strengthening of the European rail manufacturing industry on the global market.

The overall challenge: strengthening the role of rail in the European transport system and the global competitiveness of European industry

Despite many positive developments in recent years, with growth in rail markets across many parts of Northern, Western and Central Europe, namely thanks to heavy investments for instance in high-speed train infrastructure[4] and other innovative solutions, rail has still not succeeded in outpacing the road and air sectors. In some Eastern and Southern European countries, the modal shares of both freight and passenger rail have actually fallen. The overall trends in terms of European rail modal share for both freight and passenger rail transport can thus be improved. This is particularly true for freight as, today; just 10% of European cargo is carried by rail.

Yet, the growth encountered in past years in various segments of the rail sector show that rail can deliver as an attractive transport solution for urban, regional and long-distance mobility throughout Europe, providing that the right investments are made and that rail can overcome some of the inherent challenges preventing it from realising its true potential.

Helping rail to exploit the important market and revenue potentials on European transport markets will, in particular, contribute to the EU and Member States' policy objective of making more use of more energy-efficient transport modes in order to reduce greenhouse gas emissions and improve the overall environmental performance of the European transport system.

Furthermore, the development of innovative railway system technologies in support of the growth of the rail sector will also help to sustain the overall competitiveness of European rail supply industry, by creating new business opportunities, thereby generating macroeconomic benefits, summed up in increased GDP, with permanent gains to employment, productivity and net exports.

A quality of service challenge

From a customer perspective the quality of rail services continues to be perceived as insufficient. Only 58% of Europeans are satisfied with their rail services, while just 51% are satisfied with railway

[4] SWD(2013) 10 – Part 1

stations in Europe. Rail still does not come across as a user-friendly transport mode, with 19% of Europeans simply not taking the train because of accessibility issues[5].

Also on the freight transport markets, the lack of reliability and punctuality of rail freight services is a source of dissatisfaction among customers – causing potential customers to consider rail as incapable of meeting their logistical needs. Low traffic volumes have a negative effect on the economics of the system, hence on its cost competitiveness.

Customer service in the railway sector needs a radical rethink to be adapted to constantly and rapidly evolving quality expectations of users in today's hyper-connected society. The level of delivery of these services must be consistently outstanding. Rail needs to offer new added-value service features, allowing rail to (re-)enter into new or lost market segments, and enabling it to satisfy the needs of customers in all rail segments.

A cost challenge

Rail transport continues to rely to a large extent on public funding, with public subsidies to rail (public services and infrastructure) estimated at 36-38 billion EUR in 2012. Constrained public expenditure means that public investment in railway infrastructure and services must be optimised.

The railway sector will ultimately require pioneering ideas and new organisational and business processes to be able to deliver more with less, particularly putting the emphasis on how best to utilise legacy assets.

Costs per output-unit must decrease and rail’s cost competitiveness must be improved thanks to increased resource productivity, lower life-cycle costs and the realisation of economies of scale, namely thanks to the standardised specifications of components and the increased harmonisation of functions, operational rules, interfaces and products specifications. This will also help to achieve wider market uptake of innovative solutions.

A European challenge – overcoming the fragmentation of rail markets

Although transport markets are becoming more and more global, the European rail sector continues to have a strong national focus, due to technical, organisational, regulatory and cultural barriers. Of course, the internationalisation of railway services is a growing trend that is enabled namely thanks to the introduction of the Railway Directives and the associated Technical Specifications, common regulatory processes and Common Safety Methods including a common signaling system (European Rail Traffic Management System (ERTMS)). However, unlike in the aviation and road sectors where products are placed on the market for use in many Member States, many products and systems developed for the rail sector continue to be tailored to specifications unique to particular national or even regional public transport authorities, national safety authorities, railway undertaking and/or the inherent constraints of specific national infrastructure, electrification or control-command systems.

[5] European Commission: Flash Eurobarometer 382a: European's satisfaction with rail services, December2013

Major efforts will have to be pursued to ensure that the "rules and tools" necessary for the efficient operation of a shared system are integrated into the rail sector so that the fragmented national rail systems may become an integral part of a broader European mobility system and close TSI's open points.

The measures contained in the Fourth Railway Package will be crucial to overcoming these barriers. However, they will not be sufficient and the modernisation of European railways will also have to be supported through more research and innovation and through the development and deployment of new technological solutions that can overcome national differences and close TSI's open points.

A core focus will be on standardised specifications of components and on increasing harmonisation of operational rules, procedures and products specifications with a view to ensuring that products may be placed on the market for use in several Member States and that trains are more easily able to cross national and operational borders without ensuing delays or encountering barriers to authorisation and operational constraints. This will also help to reduce production costs and increase operational margins by creating economies of scale and making components more easily interchangeable and deployable throughout Europe.

An infrastructure challenge

Increased trade, travel and urbanisation drive the need for new infrastructure as well as for upgrading of legacy infrastructure. Without adequate investment and new sources of financing, infrastructure will become a bottleneck to future travel and transportation growth.

Yet, despite its many advantages, rail still often finds it challenging to secure societal acceptance for new infrastructure projects, largely due to "NIMBY" attitudes and to the fact that noise and vibrations continue to constitute a major environmental issue, in particular in the freight and high-speed passenger segments. Rail will have to seek new solutions to overcome this obstacle in future.

A competitiveness challenge

Although the European rail supply industry still leads at world level, accounting for more than EUR 49 billion of the EUR 131 billion global rail market, a recent Commission study on the competitiveness of the railway supply industry[6] shows that Asia is steadily overtaking Europe as the largest rail supply market, namely thanks to massive investments in R&I, primarily in countries like China, Japan and Korea. Many of these countries also have lower costs, including labour costs, while also heavily subsidising their industries.

Maintaining the technologically advanced position of Europe will be key to retaining its competitive position at global level and creating new business opportunities for the European rail supply industry that could contribute to major macroeconomic benefits, with gains to employment, productivity and net exports.

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[6] EC, Sector Overview and Competitiveness Survey of the Railway Supply Industry, May 2012, p. 100

This will also require tackling some current inefficiencies, such as the fragmentation of production, low level of collaboration and partnership among the rail industry, missing system approach,,etc.

A know-how challenge

The railway sector is confronted with an ageing workforce, with some 30% of the workforce expected to retire in the 10 years to come. The availability of suitably skilled people for the sector is becoming an increasing challenge, especially as competition for skills becomes increasingly globalised.

In parallel, as the pace of technological and technical changes accelerates, people working in the railway sector are not always fully equipped with the necessary skills to cope with the introduction of new technologies and techniques.

A major gap in engineering skills is likely to develop unless remedial action is undertaken to make the rail sector attractive to young engineers and to provide high quality education and training opportunities in order to provide a work force capable of dealing with an increasingly complex and technology intensive rail transport system and increase the productivity of staff.

Innovation – a tool for the long-term

Global trends towards sustainability, coupled with demographic and resource availability challenges, provide rail sector with a welcomed opportunity to play a new broader role in global transport markets. Rail must take advantage of its relative advantages in terms of environmental performance, safety and efficiency and further enhance its performance in these areas through innovation.

Innovation should be envisaged as a tool with a dual purpose of helping to address the pressing short/medium terms problems that drain nowadays business operations whilst, in parallel, initiating a paradigm shift for a more ambitious future for the rail sector.

The rail sector must prepare for a rapid and substantial evolution. It will have to think differently about its value propositions, continuously developing and improving products and services that evoke extreme responses, uncover missed customer segments, look to, check and adopt technologies and services developed in other sectors that can be a source of inspiration for brand new products and business concepts. This will require rail stakeholders to question long established principles and practices and to develop more sustainable and promising market opportunities by thinking faster, by thinking differently, by thinking partnerships and open collaboration and, above all, by thinking bold.

1.3 What is the Shift2Rail Strategic Master Plan?

In accordance with Article 2(1)(c) of the S2R Regulation, one of the core tasks of the S2R JU is to establish and develop — and ensure the effective and efficient implementation of — a strategic Master Plan. As defined in Article 1(4) of the S2R Statutes, this strategic Master Plan is a forward-looking strategic roadmap to drive innovation in the rail sector in the long term, looking at a 2030 horizon. It is the key document to define the strategy of the S2R JU to develop, integrate, demonstrate and validate innovative railway technologies and solutions with the objective to improve the competitiveness and attractiveness of the Railway Sector in Europe.

By defining long-term priorities which are commonly agreed by the European Union and key private actors of the European Rail Sector, the Master Plan will be the basis for a better cooperation between Research and Innovation stakeholders and decision-makers of the European rail sector and will provide the right framework for European industry to anchor their research and innovation investments in Europe. Moreover, the definition and implementation of a common research and innovation agenda, in close cooperation with all market players, will ensure the economic benefit, quality and relevance of future R&I projects, thereby facilitating the commercial exploitation of research results. This integrated and coordinated approach will also help to make rail research and innovation funding across the EU more efficient, coherent and less risky, thanks to the sharing of financial, human and infrastructure resources, leading to economies of scale and reduced costs for all partners involved.

The rail sector at large, including hundreds of stakeholders from across Europe, representing the rail supply industry, infrastructure managers and railway undertakings and urban operators, as well as SMEs, research organisations, users / customers groups and universities, have been working together over the past 3 years to define priorities and developing a technical proposal for Shift2Rail.

This input provided a strong basis for the S2R Master Plan, which has been developed by the founding members of the S2R JU, including the Commission, and in consultation with the European Railway Agency (ERA), the European Rail Research Advisory Council (ERRAC) Technology Platform, and other key stakeholders.

The present document was adopted by the JU Governing Board on 31 March 2015, following its endorsement by the Council on 10 February 2015. In accordance with the S2R Regulation, any subsequent modification shall be endorsed by the Council, acting on a proposal from the Commission, and communicated to the European Parliament.

2 Objectives and general approach of the S2R JU

2.1 Shift2Rail objectives

Rail research conducted within the S2R JU must contribute to addressing the challenges faced by the rail sector, through a comprehensive and coordinated approach to research and innovation and focusing on the needs of the rail system providers and users.

In particular, the Shift2Rail activities should prioritise the following general objectives:

- Achieve the **Single European Railway Area** through the removal of remaining technical obstacles holding back the rail sector in terms of interoperability and through the transition to a more integrated, efficient and safe EU railway market, guaranteeing the proper interoperability of technical solutions.

- Radically enhance the **attractiveness and competitiveness** of the European railway system to ensure a modal shift towards rail through a faster and less costly transition to a more attractive, user-friendly (including for persons with reduced mobility), efficient, reliable, re-designable and sustainable European rail system.

- Help the European rail industry to retain and consolidate its **leadership on the global market** for rail products and services by ensuring that R&I activities and results can provide a competitive global advantage to EU industries vis-à-vis foreign competition and by stimulating and accelerating the market uptake of innovative technologies.

In order to meet these overarching objectives, the rail sector must be able to deliver increased quality of services at affordable costs and ensure proper interoperability of technical solutions. In addition, special attention should be given to reducing the costs of developing, certifying and authorising, implementing, operating and maintaining,new solutions, as they constitute a significant barrier to the market uptake of innovative technologies.

The expected outcomes of the Joint Undertaking can therefore be structured around the four following specific objectives:

- **Improved services and customer quality.** The aim is to improve the attractiveness of rail services through innovative solutions and adapt them to the constantly and rapidly evolving quality expectations of users, while ensuring consistently excellent delivery. Three different elements have to be taken into account:

    - Firstly, the operational reliability of rail will have to be substantially improved to make rail transport a more punctual, safe and secure travel and shipment option that is resilitent to extreme conditions and climate change. In the long term (by 2030), a 50% increase in the reliability and punctuality of rail services should be achieved.

    - Second, the capacity of rail will have to be enhanced, in particular through improved capacity management, to meet increased demand for passenger and freight railway services. In the long term (by 2030), a 100% increase in the capacity of the railway transport system should be achieved.

  - Thirdly, rail will have to offer an improved customer experience, for both passengers (including persons with reduced mobility) and freight, enhancing accessibility, offering more transport and travel options in a more flexible manner, with more speed, more comfort, more reliability and availability of additional services such as personalised information and integrated ticketing solutions for a seamless combination of transport modes for both passengers and goods.

- **Reduced system costs.** The long-term objective (by 2030) should be to achieve a 50% reduction of the life-cycle cost of the railway transport (i.e. the costs of developing, building, maintaining, operating, renewing and dismantling infrastructure and rolling stock), while also reducing negative externalities. In particular, three different elements have to be taken into account and balanced out to lead to an optimal reduction of system costs:

  - Where feasible, the investment costs of new rolling stock, infrastructure or technical solutions (including renewal and/or upgrade of existing assets) should be significantly reduced to facilitate the uptake of more modern and efficient technologies.

  - Second, expenditures linked to the operation of services, including long-term maintenance and energy consumption should be reduced.

  - Third, indirect costs of externalities such as noise, vibrations, emissions and other environmental impacts, should be addressed to make rail an even more sustainable transport solution.

- **Enhanced interoperability**. The aim is to remove remaining technical obstacles holding back the rail sector in terms of market opening for supply of rail products, connectivity and efficiency, and thereby enabling economies of scale while maintaining and improving the safety standards. The two main elements on this matter are the respect and if necessary the adaptation of the existing target system specifications (TSIs) and the identification of the need to remove current open-points to apply future technological solutions.

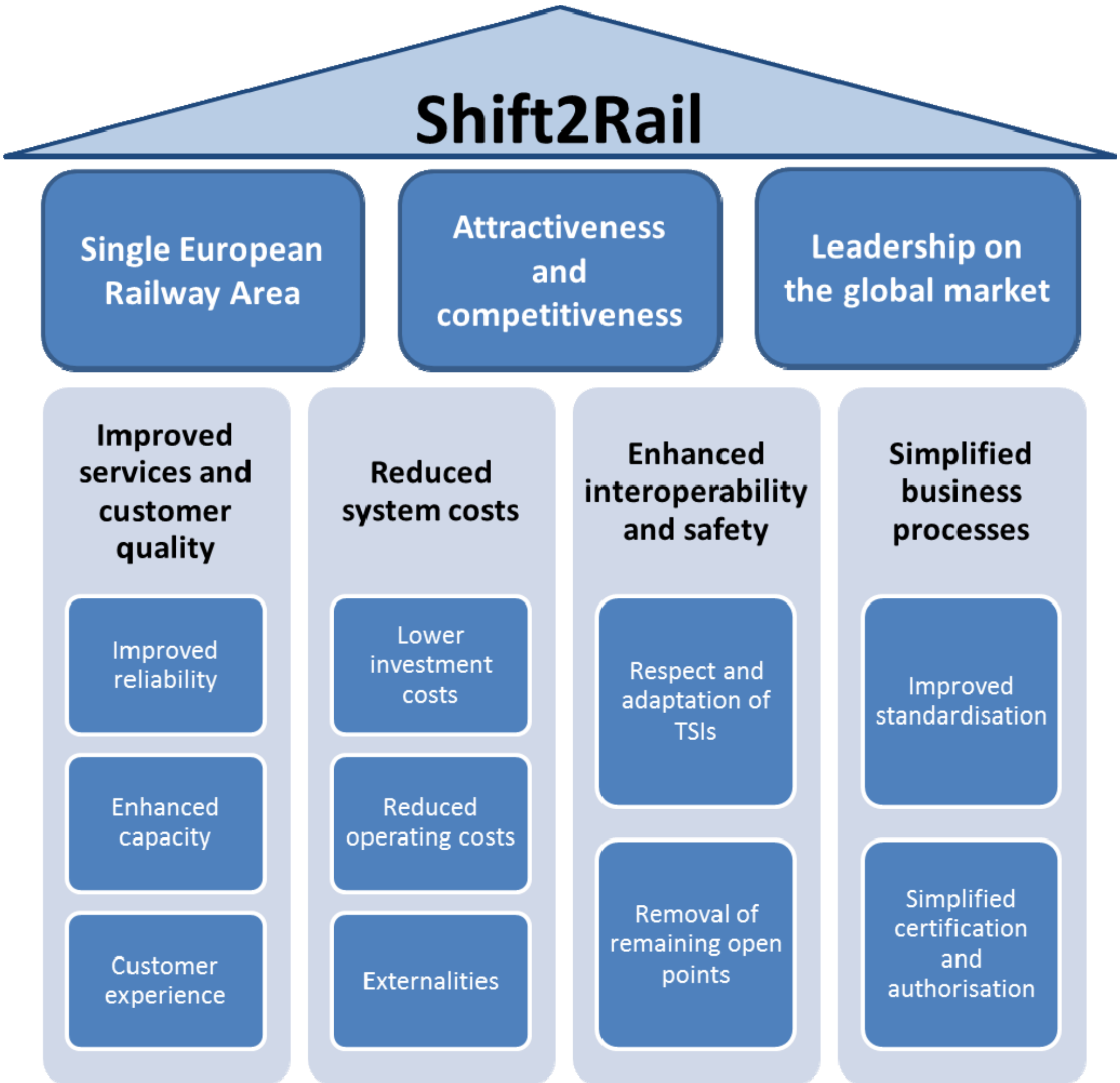
- **Simplified business processes**. The aim is to reduce the development and productions costs of innovative technologies. A reduction of the costs of developing, certifying and authorising new systems will not only benefit the rail supply industry but also have a positive impact in terms of reduced capital investment costs for the rail operating community, thereby contributing to reduced system costs. Improvements can be achieved mainly through three elements: harmonisation of specifications, improvement of the requirement process and the simplification of the authorisation procedures, leading to reduced development and production costs.

Measures contributing to these four specific objectives are all inter-connected and contribute to achieving the general objectives of the S2R JU. For instance, the introduction of standardised interfaces and specifications of components for Advanced Traffic Management and Control Systems will not only have an impact on the complexity of business process but is likely to lead to reduced investment costs and enhanced interoperability and modularity. Similarly, any innovative solutions for rail that will be developed or adopted by European companies will, when implemented, not only have an impact on the costs and quality of services offered by rail operators, but will also increase the European suppliers' and service providers' worldwide competitiveness, and thus consolidate the leadership of the European industry on the global market of rail products and services. For this reason, these objectives will only be achieved by all parties working in partnership.

At the same time, the performance of the whole rail system depends largely on transversal issues such as human factors, safety, sustainability, etc.

The following figure presents the intervention logic of Shift2Rail, illustrating how the objectives are interconnected.

Figure 1: Intervention logic of Shift2Rail



For the European Union at large, the technical innovations developed under Shift2Rail will deliver many benefits including a reduction in pollution, a more efficient, affordable, sustainable and better performing rail system for the tax income spent funding the public transport systems, more job opportunities for the requirement of private and public investments and a reduction in investment needed for new lines and rolling stock as a result of increases in efficiency and capacity.

2.2 Systems approach

The performance of the railway system will only be improved if it is understood and managed as a whole system shared between many actors, with particular attention to the interfaces between the parts of the system managed by the different actors. Furthermore, rail transport must be fully integrated in the overall transport system with close links to other modal networks: airports, ports, metro and bus stations, and all type of individual transport means in order to provide attractive and seamless transport services for freight and passengers. A cross-sector, whole-system approach to design, maintenance, delivery and safe operation should be adopted.

For this reason, the research in Shift2Rail will be based on a holistic view of the railway system that allows for the inclusion and consideration of all relevant railway subsystems and actors but also their complex interaction. This complexity will, insofar as possible, be managed by means of common definition of terminology and programme-wide management of technical requirements across system and sub-system boundaries, leading to improved performance.

Such a system approach will require the input and participation of different railway actors, including the broader supply industry, the railway operating community, standardisation organisations, ERA and safety authorities. Cross-industry coordination of the design and development of subsystems and components will reduce duplication and minimise negative cross-system impacts. Cooperation with actors from other modes is key in order to apply innovations form other sectors also in the railway domain and to develop high quality and seamless mobility solutions.

This whole-system approach will enable the rail supply industry to adapt more easily to change and to implement innovative new designs and methods that meet the rail operating community and the users' needs, providing customers with a much more attractive transport solution. It will also contribute to increased reliability, availability, maintainability and safety at reduced cost, thereby contributing significantly to the emergence of a Single European Railway Area (SERA).

Given this systems approach, the work conducted within the Shift2Rail framework will be structured, first of all, around five asset-specific Innovation Programmes (IPs), covering all the different structural (technical) and functional (process) sub-systems of the rail system, namely (see chapter 3.1-3.5):

- IP1: Cost-efficient and Reliable Trains, including high capacity trains and high speed trains;
- IP2: Advanced Traffic Management & Control Systems;
- IP3: Cost-efficient, Sustainable and Reliable High Capacity Infrastructure;
- IP4: IT Solutions for Attractive Railway Services;
- IP5: Technologies for Sustainable & Attractive European Freight.

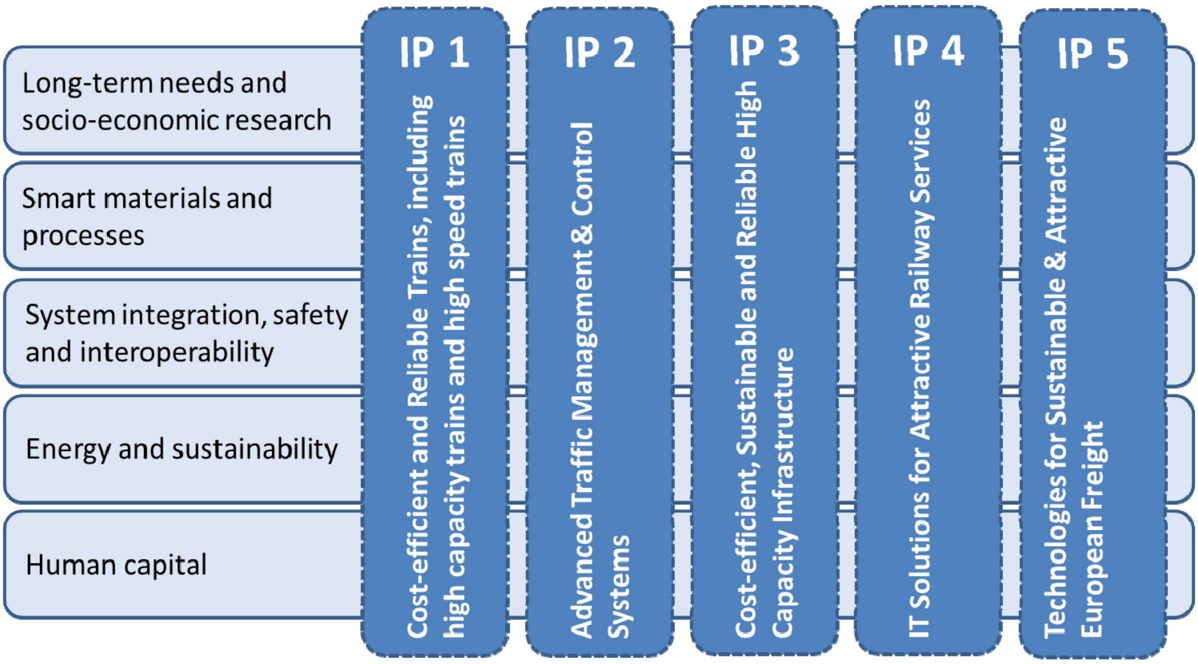
These five Innovation Programmes are not just a simple "package" of programmes that are independent of one another. On the contrary, they form a whole assembly of the railway system, with a number of common cross-cutting themes and the R&I activities of the Joint Undertaking have to be managed in the most efficient way to allow the full coverage of all areas while ensuring a high degree of efficiency in the management of the technical activities.

For this reason, in addition to the five Innovation Programmes, the work of Shift2Rail will also be structured around five cross-cutting themes that are of relevance to each of the projects and takes into account the interactions between Innovation Programmes and the different subsystems (see chapter 3.6):

- Long-term needs and socio-economic research
- Smart materials and processes
- System integration, safety and interoperability
- Energy and sustainability
- Human capital

The interactions between the different IPs will be of major importance, given that evolutions in the technology in one part of the system can lead to changes in performance or even create barriers that are visible in another part of the system managed by another actor. In addition, cross-cutting activities will also include research on long-term economic and societal trends, such as customer needs, human capital and skills, which are necessary to be taken into account by the different Innovation Programmes.

Figure 2: Shift2Rail systems approach and cross-cutting themes



At all times, Shift2Rail will seek to nurture collaboration across the railway sector, promoting collaboration and knowledge transfer processes between industry, academia and research institutions.

Shift2Rail will also facilitate cross-fertilisation from other sectors by involving key players from other transport sectors, but also from other industrial sectors, such as IT, telecommunications and energy sectors.

2.3 Typology of Shift2Rail Research and Innovation activities

A sustainable growth of the rail sector requires a dedicated and balanced approach addressing specific common research and innovation challenges, while integrating and demonstrating cooperation between stakeholders across the whole rail value chain.

Responding to these challenges will require different types of activities, including:

- **Demonstration activities**
- **Research and technological development activities**
- **Other supporting activities**

On top of these three types of activities that are funded and conducted directly by the S2R JU, the Members of the Shift2Rail JU will be required to conduct additional activities with a view to leveraging the effect of the R&I activities undertaken within Shift2Rail. These activities are not eligible for financial support by the S2R Joint Undertaking but must contribute directly to the broader objectives set out in the Shift2Rail Master Plan.

2.3.1 Demonstration activities

An important focus of Shift2Rail will be on demonstration activities, which are needed to deliver a quantified impact, but also to provide guidance on the most efficient combinations of these technologies, and assess the potential for improvement to the national, EU transport network and SERA. To this end, demonstration projects will mainly contain activities corresponding to Technology Readiness Level (TRL) levels 4 to 7 (i.e. from technology development in lab to system prototype demonstration in operational environment)[7].

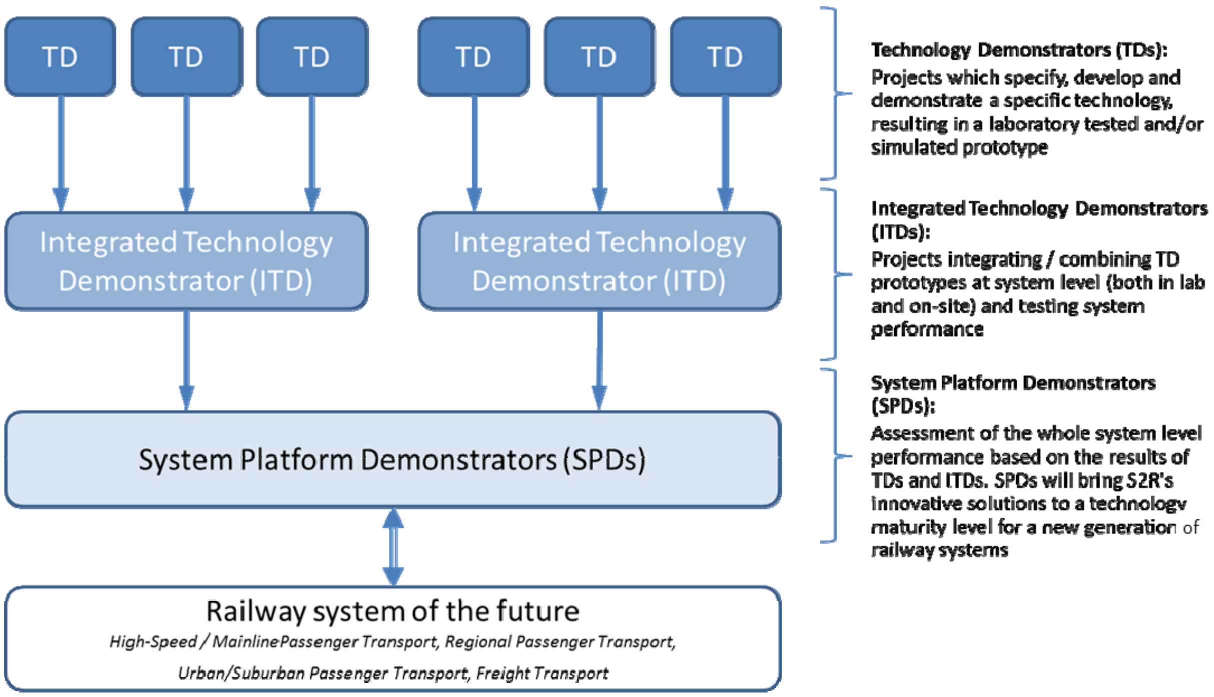
These activities are considered as being the last non-commercial step to demonstrate the operational performance and reliability of all deliverables from the technology demonstrators (TDs) so that the first commercial units can be designed, with guaranteed performance based on the outcome of the demonstration activities. The scale / maturity of demonstrators TRL 4-7 should be

[7] An explanation of the concept of TRLs can be found in Annex of the Horizon 2020 work programme. The following descriptions apply: TRL 1 – basic principles observed; TRL 2 – technology concept formulated; TRL 3 – experimental proof of concept; TRL 4 – technology validated in lab; TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies); TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies); TRL 7 – system prototype demonstration in operational environment; TRL 8 – system complete and qualified; TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

high enough to be able to prove technical, environmental and economic performance in an equivalent operational system environment (real (physical) and/or simulated), and provide enough data so that the technology can be realistically scaled-up to close-to commercial scale. Follow-up flagship projects could then be funded through deployment-oriented programmes, such as the Connecting Europe Facility (see chapter 1.1.2.2). These would mainly include demonstrator activities corresponding to TRL 7-8.

The demonstration of technical achievements will be based on the following three-fold architecture: technology demonstrators (TDs), integrated technology demonstrators (ITDs) and system platform demonstrators (SPDs).

Figure 3: Interactions between the different types of demonstration projects under S2R



Technology Demonstrators (TDs)

Technology Demonstrators will focus on the development or adoption of innovative technologies and models *within* the rail sub-systems identified in the Innovation Programmes. They will enable ground-breaking progress in key areas such as traction, automatic train operation and intelligent diagnosis and maintenance systems. They will seek inspiration from innovative technologies, materials and methods used or explored in other sectors. The innovations developed may consist of software and/or hardware systems.

Before being combined into Integrated Technology Demonstrators (ITDs), each TD will be tested (in labs on test benches, or existing trains) in one or more prototypes (differentiated if different business segments are addressed) to assess the individual performance of the technologies thus developed, and, where possible, demonstrate the conformity with technical requirements that apply to the product developed.

Integrated Technology Demonstrators (ITDs)

The ITDs will allow for the testing of combinations of components and sub-systems already verified and validated within the Technology Demonstrators within virtual or physical railway environments for demonstrating the innovation potential of the components in different sub-systems and systems, taking into account functional and operational specifications and the technical interfaces among the various TD.

ITDs will also enable the analysis of compliance with the regulatory requirements, and the validation of technologies will be followed up with a controlled approach to future certification work.

System Platform Demonstrations (SPDs)

Ultimately, Shift2Rail will carry out proof of rail systems, design and functions on fully representative innovative railway configurations in an integrated environment and close to real operational conditions. To simulate and test the interaction and impact of the various systems in the different rail market segments, demonstration platforms are proposed covering high-speed passenger rail, regional passenger rail, urban/suburban passenger rail and rail freight. The choice of demonstration platforms is geared to the most promising and appropriate market opportunities to ensure the best and most rapid exploitation of the results of Shift2Rail.

Rail market segments for System Platform Demonstrations (SPDs)

High speed / mainline passenger rail

High speed has been a very successful and innovative rail market segment for several decades, and is often the preferred choice for long distance national and international travel, with distances up to 700/1000 km or a door to door duration of up to 4 hours. The technical and technological challenges related to high-speed and mainline rail are not just related to the development of new types of rolling stock that provide comfortable transportation capacity for increasing numbers of passengers, but also to safe and efficient operation thanks to appropriate infrastructure design, enhanced traffic control and management systems, more efficient power systems, as well as shared track and corridor operations.

Regional passenger rail

Regional rail is already serving as a backbone of the European transport system, expanding massively in past years. However, it is a segment that remains affected by competition with the private car and by the cost of operation compared to bus services. This rail market segment is also one for which existing rail infrastructure right-of-way is not used according to its potential for supporting more sustainable land use and transport policies. These services are mostly operated under public service contracts and may share or not the infrastructure with mainline traffic. What is mostly at stake is making these services more attractive to customers, through increased reliability, frequency and speed and cutting costs, as well as an improved coordination with other public transport services and a better integration in regional mobility strategies. Innovative low-cost solutions are also needed for regional network with low traffic volumes in order to ensure that they become or remain attractive for passengers.

Urban and suburban rail

Railway networks in urban and suburban areas play a prominent role in major cities and high-density areas, serving the daily needs of urban populations and offering an attractive alternative to the use of private car in congested and polluted areas. The core challenge for these segments is mainly to offer increased capacity to ever-increasing number of passengers, through improved system capacity, with enhanced traffic management and automation concepts and high-capacity rolling stock. Cost effectiveness and increased attractiveness are also important challenges, requiring higher scales of proven, affordable technology and improved accessibility, comfort and security and innovative services based on ITS. Improvements through technical harmonisation of interfaces and of will also be required.

Rail freight

Rail freight is a key element in the establishment of a sustainable transport system, as recognised in the 2011 Transport White Paper. An efficient and reliable, high-quality rail freight system in Europe is indispensable for the competitiveness of the European economy, its industries, businesses and society, which are all making use of and rely on rail freight services. The low level of external costs generated by rail freight should make it the mode of choice for freight customers looking to reduce their environmental impact. Indeed, rail is the most eco-friendly land transport mode for freight, with much lower CO_2 emissions and energy consumption per tonne-kilometre than road freight or transport by inland waterways. However, the key challenge for rail freight to become a core link in intermodal transport is for it to be able to offer an attractive, reliable, rapid and cost-efficient alternative to road.

2.3.2 Research and technological development activities

The S2R JU will also manage collaborative research activities consisting mainly of applied research, and the development and experimental proof of technologies and concepts aimed at a significant advance beyond the established state-of-the-art (corresponding to Technology Readiness Levels -TRL 1-3).

These research and technological development activities can be of three types:

- Dedicated research projects on the development of specific technologies and concepts to fill the gaps in innovative technologies, and in business, organisational and logistic solutions;
- Strategic studies, such as for instance deriving the future demand for rail services from long-term trends;
- Projects addressing cross-cutting activities supporting the successful take-up of technology innovations (see chapter 3.6).

2.3.3 Other supporting activities

The S2R JU will also be tasked with carrying out other activities in support of research and demonstration activities, such as:

- carrying out management activities, over and above the technical management of individual work packages, linking together all the project components, as well as setting up adequate monitoring, evaluation and quality assurance processes;

- pooling, reviewing and commenting user requirements and proposing interoperability standards with a view to guiding investment in research and innovation towards operational and marketable solutions;

- conducting activities to communicate and disseminate research results and to prepare for their take-up and use, including knowledge management, communications and activities directly related to the protection of results;

- liaising with relevant stakeholders and establishing links with related European, national and transnational research and innovation activities in the rail technical domain.

3 Shift2Rail Innovation Programmes and Activities

For each Innovation Programme, the current document will identify the challenge, the objectives and the proposed research and innovation activities for delivering these objectives.

The S2R JU will be tasked with clarifying how the research and innovation activities set out in the Master Plan will be prioritised throughout and beyond the lifetime of the Joint Undertaking, taking into account the following criteria:

- Scale of impact on the Shift2Rail objectives of improved services for users and customer quality, reduced system costs, simplified business processes and enhanced interoperability, in particular;
- Business benefits in terms of market uptake in Europe and globally;
- Available resources;
- Proportionality, feasibility and acceptability;
- Potential for accelerated deployment;
- Value-added of action at EU level;
- Link to ongoing research and innovation activities, in particular to projects funded under previous EU Research Framework Programmes;
- Potential synergies with other sectors.

This prioritisation should be regularly reviewed by the Shift2Rail Governing Board based on obtained results and updated ambitions of the Joint Undertaking (at least every 2 years).

This prioritisation will result in the elaboration of a result-oriented multiannual action plan and annual work plans. These work plans will include a detailed plan of the research and innovation activities, the administrative activities and the corresponding expenditure estimates for each year.

The research and innovation activities undertaken by S2R will build upon existing R&I projects and should, wherever possible, analyse, exploit and complement the results and developments that may already be funded by other EU programmes, such as FP7 projects, CEF, etc.

3.1 *IP1: Cost-efficient and reliable trains, including high capacity trains and high speed trains*

3.1.1 Challenge

The design of rolling stock plays a key role for the attractiveness of rail transport. Only trains that are comfortable, reliable, affordable and accessible can convince passengers to use rail transport instead of other modes. At the same time, the train design has to meet the requirements of the railway undertakings and the urban operators, who are the main customers of the rail supply industry, in order to deliver high quality and cost-efficient services to their customers.

A combination of rail customers' ever-evolving requirements for rail passenger vehicles regarding quality of service, time constraints, mounting energy costs, more stringent emission standards, and increasing stress on the economics of rail operation is generating a new wave of challenges to rail vehicle development.

If rail is to compete more effectively with other modes and attract more passengers in the future, it needs a future generation of passenger trains that will be lighter, more energy and cost-efficient while at the same time providing a comfortable, safe and affordable travel experience for all passengers.

These innovations should therefore not only be limited to the traditional, incremental approach to vehicle development but also result from a whole new way of thinking on product development.

In order to introduce the future generation of passenger trains an innovative system approach is needed, which includes the development of innovative and modular solutions for comfortable and attractive train. Other important parts of the holistic passenger train concept are the development and integration of higher-performance technologies for traction and critical structural components, command-control and cabin environment applications, as well as flexible, reliable and safe design and production solutions. At the same time, innovative solutions to extend vehicle lifetime, or simplify retrofitting and to ensure that networks can support the operation of these vehicles need to be developed.

3.1.2 Objectives

Objectives		Desired outcomes
Improved services and customer quality	Improved reliability	Reliability, performance and safety of vehicles are increased thanks to the improvement and simplification of train subsystems (including their interfaces) that are known to be more prone to operational failure (e.g. TCMS, Traction, Brakes, etc.) and the better resilience of trains towards extreme environmental conditions is improved.

	Enhanced capacity	The vehicles' capacity is increased as a result of new rolling stock technologies, improved interior design and innovative passenger access systems. Better operational reliability of trains will contribute to more consistent service provision and customer satisfaction that will be further supported by activities in IP2.
	Customer Experience	Unique traveller experience is delivered thanks to comfortable and attractive train interiors. Innovative vehicle access systems will allow independent and faster boarding and more space for passengers in each vehicle (including passengers with reduced mobility). Full consideration is given to the requirements of train operators in terms of cost-efficient, reliable and safe rail vehicles with a high degree of operational flexibility.
Reduced system costs	Lower investments costs	Improved and simplified authorisation processes lead to a reduction of the capital costs of vehicles. Modular design solutions allow a more flexible use of vehicles. Retrofitting of radically innovative solutions enable extended vehicle lifetime. A more standardised approach to requirements and interfaces of vehicles and its subsystems will lead to greater efficiency and lower procurement and operational costs.
	Reduced operating costs	Operational costs are reduced through the introduction of innovative technologies allowing a more efficient use of energy. In particular, energy efficiency is increased thanks to improved traction and braking systems, higher aerodynamics performance, reduced weight of train components and a reduction in thermal losses (i.e. doors) and improved driver awareness of energy-saving driving techniques. In addition, the cost of maintenance of other parts of the railway system are reduced thanks to track friendly vehicles with lower axle loads, lower unsprung mass, better curving performance and ability to run through switches and crossings.
	Externalities	Noise, emissions and vibrations are reduced through new innovative design features for traction, brakes, running gear, carbodyshell and doors. This will improve the acceptance of rail transport by the public.
Enhanced interoper ability	Respect and adaptation of TSIs	Opportunities are generated to, where necessary, adapt and improve the Technical Specifications for Interoperability to take advantage of scientific and technical progress.

	Removal of open-points	Remaining technical “open points” in existing target system specifications (TSIs) should be closed, in particular when it comes to doors, safety, EMC compatibility of rolling stock with train detection systems, eddy current track brake compatibility with the network, etc.
Simplified business processes	Improved standardisation	More standardised and reliable system architectures and component technologies are introduced. This contributes not only to lower investment, maintenance and retrofitting costs for vehicles, but also to a more efficient and attractive rail system
	Simplified certification and authorisation	Simplification of authorisation processes by the introduction of virtual certification rather than on-track tests.

3.1.3 Indicative list of priority research and innovation activities

With a view to achieving the above objectives and outcomes, research and innovation activities within IP1 should focus on the following areas and activities:

Area	Activities
Train interiors	The development of new criteria and standards to evaluate passenger comfort and attractiveness of train interiors and of innovative and modular design solutions for train interiors that enable the introduction of novel on-board value-added services and improve important aspects of passenger comfort, such as accessibility, noise and vibrations.
Doors and intelligent access systems	Innovations in passenger access systems along with new solutions for autonomous boarding of persons with reduced mobility will optimise the flow of passengers and enhance system capacity and attractiveness. Entrance systems with enhanced energy efficiency characteristics and thermal and acoustic performances will enhance passengers comfort.
Traction	New traction components and components using new semi-conductor technologies and architectures to provide reliable, resilient, cost-effective, environmentally friendly and smart new power trains. New methodologies and tools to design and validate reliable traction systems and components with reduced volume, weight and noise emissions and improved energy efficiency and electro-magnetic compatibility.

	New technologies for energy storage and alternative ways to convey energy to the vehicles should also be examined.
Train Control and Monitoring System (TCMS)	New generation TCMS architectures and components with wireless capabilities, enhanced throughput and safety and security functionalities. Activities shall include the development and demonstration of more reliable and safe train control systems by reducing the number of components, optimising the architecture and integrating safety critical functions. More flexible and modular functional architectures shall be developed making it easier to enhance, upgrade, retrofit and (re)authorise the TCMS, while increasing availability. The possibility and challenges of combining TCMS equipment with on-board control-command-signalling systems should be investigated.
Carbodyshell	Lighter and aerodynamic carbodyshell structures based on up to 100% composite materials to reduce energy consumption. Activities will aim at a better integration of sub-systems and train components, leading to less complex manufacturing processes and easier maintenance and repairs and positive effects on the life cycle costs.
Running Gear	Next generation of light weight bogie systems with reduced infrastructure/wheel wear and damage and energy loss, whilst providing higher reliability and availability with lower maintenance costs. Lighter running gear based on optimised materials as well as new active suspensions and bogie control technologies in order to reduce wear, noise and vibration levels.
Brakes	Safer and better performing brake system with lower life cycle costs and noise levels, and recovery of the braking energy. Lighter, more compact and environmentally-friendly brake systems and a new generation of brake control electronics. Improved adhesion management, new generation of eddy current brakes as well as diagnosis enhancements for easier and more cost-efficient maintenance.

3.2 *IP2: Advanced Traffic Management & Control Systems*

3.2.1 Challenge

Control, command and communication systems should go beyond being only a contributor for the control and safe separation of trains and become a flexible, real-time, intelligent traffic management and decision support system.

Although ERTMS has become a worldwide dominant solution for railway signalling and control systems, it has the potential to offer increased functionalities and become even more competitive. Current systems do not sufficiently take advantage of new technologies and practices, including use of satellite positioning technologies, high-speed, high-capacity data and voice communications systems (Wi-Fi, 4G/LTE), automation, as well as innovative real-time data collection, processing and communication systems, which have the potential to considerably enhance traffic management (including predictive and adaptive operational control of train movements), thereby delivering improved capacity, decreased traction energy consumption and carbon emissions, reduced operational costs, enhanced safety and security, and better customer information.

Furthermore, ERTMS specifications do not cover all interfaces, or engineering and operational rules to the extent needed, meaning that different railways and suppliers continue to design their own solutions, thereby hampering interoperability and increasing costs.

Therefore Shift2Rail activities should support the rapid and broad deployment of advanced traffic management and control systems, by offering improved functionalities and standardised interfaces, based on common operational concepts, facilitating the migration from legacy systems, decreasing overall costs, adapting it to the needs of the different rail segments as well as to the needs of a multimodal smart mobility system.

A major goal of Shift2Rail is to raise competitiveness of European solutions in the world context and to achieve its aims across different modes of railways.

A key challenge for Shift2Rail IP2 will be to enhance the advanced traffic management and control systems without impacting the ERTMS core and, where appropriate and necessary, by providing backwards compatibility to protect investments both in mainline and urban railways. In Shift2Rail, the involvement of ERA (as the system authority for ERTMS) is therefore essential. ERA will ensure the involvement and contribution of Sector Organisations active in the relevant ERTMS Working Groups, monitoring the part of the IP2 system roadmap related to ERTMS and ensuring that a proper configuration management will be followed in order to preserve both the short-term stabilisation of the specifications and the long-term evolution of ERTMS.

3.2.2 Objectives

Objectives		Desired outcomes
Improved services and customer quality	Improved reliability	Improved punctuality and reliability as trains are managed more efficiently with reduced risk of failure or disruption thanks to advanced traffic management systems, smart decisions support systems and simplified architectures more suited for operational recovery in case of failure.
	Enhanced capacity	Better use of (existing or new) infrastructures by operating with more trains on the same line (lower headway). More flexible use of the vehicles on the line allowing a higher level of service to passengers and freight operators at peak times.
	Customer Experience	Increased punctuality and use of accurate and real-time data for improved passenger information.
Reduced system costs	Lower investments costs	Reduction of overall investment costs thanks to the introduction of flexible architectures and application of engineering standards, allowing a correct system design adapted to the requirements of different market segments (from Freight to Mass Transit)
	Reduced operating costs	Fewer, optimised and predictive maintenance interventions thanks to the broad introduction of auto-diagnostic functions and self-healing processes, as well as to a reduction in the number of electronic and mechanical components installed along the line. Reduction in the consumption of energy with the introduction of Intelligent Traffic Management, Driver Advisory Systems (DAS) and appropriate automatic train operation (ATO) functionalities in all rail transport market segments.
	Externalities	Decrease in carbon emissions and air pollution thanks to enhanced traffic management (including predictive and adaptive operational control of train movements).
Enhanced interoperability	Respect and adaptation of TSIs	New control system design takes into account interfaces with other sub-systems and uses generic designs and layouts, standardised interfaces and specifications of components, and a holistic approach, thereby enabling rapid and cost-efficient construction and deployment as well as improved interoperability. Extending synergies and compatibility with the urban and mass transit railway sectors

	Removal of open-points	Remaining technical "open points" in existing target system specifications (TSIs) should be closed, in particular when it comes to electro-magnetic compatibility. Calculation of train data should be harmonised and the "integration" of ETCS in the train should be improved.
Simplified business processes	Improved standardisation	Introduction of formal methods and assisted or automated testing process/tools - from specification up to commissioning phase - to key elements, components and systems the failure of which might cause major impact on line operation (e.g. signalling, telecom). Modular architectures are introduced to divide the validation effort, provide higher granularity interfaces for testing and allow system extensions. The process of software update should be improved, taking into account for example the "over the air" (OTA) updating model.
	Simplified certification and authorisation	Improved and shorter authorisation processes, relying on lab methods rather than on on-track tests.

3.2.3 Indicative list of priority research and innovation activities

With a view to achieving the above objectives and outcomes, research and demonstration activities within IP2 should focus on the following areas and activities:

Area	Activities
Smart, fail-safe communications and positioning systems	Overcome shortcomings in current ETCS and CBTC and deliver an adaptable communication system for train control applications in all market segments, using packet switching/IP (GPRS, EDGE, LTE, Satellite) technologies, enabling easy migration from legacy systems, providing enhanced throughput, safety and security functionalities to support the current and future needs of signalling systems, and resilient to interference and to radio technology evolution. Develop a fail-safe, multi-sensors train positioning system (e.g. by applying in demonstrator GNSS to the ERTMS/ETCS core), boosting the quality of train localisation and integrity information while reducing the overall cost, namely by enabling a significant reduction in all track-side conventional train detection systems (balises, track circuits, axle counters, etc.).

Traffic Management Evolution	Advanced traffic management systems should be automated, interoperable and inter-connected. They should be combined with Driver Advisory Systems (DAS) and automation functionality to allow for predictive and dynamic traffic management in regular and degraded situation, integrating and using real-time status and performance data from the network and from the train, using on-board train integrity solutions and network attached object control functions, supported by wireless network communication. Systems should be scalable and easily upgradable, using standardised interfaces and specifications of products, and enabling easy migration from legacy systems. They should rely on harmonised train data and data calculation methods, using improved algorithms to reach normal operation following disturbances in the network.
Automation	Develop and validate automatic train operation (ATO) for ETCS, where applicable, up to Grade of Automation (GoA) 4 (unattended train operation) for urban and suburban applications, and at least GoA2 (semi-automated train operation) for other market segments, including freight lines.
Moving block (MB) and train integrity	Develop and validate a high capacity, low cost, highly reliable signalling system based on moving block principles, thereby allowing more trains on a given main line, especially for high density passenger services. The system should be backward compatible with existing ERTMS system specifications and enable evolutions towards CBTC functionalities for Urban applications. The train integrity function shall be developed in the same time.
Smart procurement and testing	Develop an approach for zero on-site testing using simulation tools and demonstrators in a laboratory. Develop standardised engineering and operational rules and contribute to open standard interface (if supported by positive business case) and functional ETCS description model, all based on formal methods, in order to ease verification and authorisation processes, eventually leading to improved interoperability, while reducing the need for extensive field tests in future.
Virtual coupling	Explore the concept of virtual coupling/uncoupling in order to maximise the flexibility of train operations and allow a higher level of service to be provided to passengers and freight operators, while allowing a reduction in fleet use. This would represent a paramount change of the approach to fail safe train distance concept in the railways field.

Cyber security	Achieve the optimal level of cyber-security against any significant threat for the signalling and telecom systems in the most economical way, as well as protection from Cyber Attacks and Advanced Persistent Threats coming from outside.

3.3 IP3: Cost Efficient and Reliable High Capacity Infrastructure

3.3.1 Challenge

The design, construction, operation and maintenance of rail network infrastructure has to be safe, reliable, supportive of customer needs, cost-effective and sustainable. Furthermore to deliver the benefits of market opening and interoperability and to reduce the life cycle costs of rolling stock and on-board signalling systems there needs to be a (gradual) elimination of network diversity through a migration towards a common high-performing infrastructure system architecture.

Infrastructure accounts for approximately one-third of the railway's operating costs[8] and EU Member States spent some 29-34 billion EUR on railway infrastructure in 2012[9].

A significant part of these costs are related to labour-intensive maintenance, most of which is preventive, although ad hoc interventions are also needed when faults occur and these can be particularly costly and disruptive. Taking to account the ageing of existing infrastructure and the expected growth in passenger and freight volumes (+34% and +40% in 2030 respectively, compared to a 2005 baseline), leading to shorter infrastructure access times, maintenance needs and costs are likely to increase significantly in the coming years. Therefore, Shift2Rail must first and foremost focus on activities that can support the reduction of these maintenance costs, such as simplified procedures or automation, and on solutions that can be rapidly and efficiently deployed.

At the same time, many parts of existing railway infrastructure (railway lines, stations and terminals) are nearing maximum capacity or are incapable of offering users and customers the level of service they demand. There is thus a need for a step change in the productivity of infrastructure assets. These will have to be managed in a more holistic and intelligent way, using lean operational practices and smart technologies that can ultimately contribute to improving the reliability and responsiveness of customer service, as well as the capacity and the whole economics of rail transportation.

Lastly, in order to support vital pan-European rail corridors and co-modal links and offer a smart and competitive alternative to short and medium-distance flights and water and road-borne freight flows, rail infrastructure must ensure compatibility between infrastructures (interoperable and standardised infrastructure), as well as with other modes(intermodal infrastructure, including stations and passenger and freight hubs).

[8] Technical Strategy Leadership Group (TLSG): The Future Railway: The Industry's Rail Technical Strategy 2012,
[9] http://ec.europa.eu/transport/modes/rail/market/doc/swd%282012%29246_final-2_-_annex_to_the_report.pdf

3.3.2 Objectives

Objectives		Desired outcomes
Improved services and customer quality	Improved reliability	Key components and systems that are known to be more prone to operational failure (e.g. switches and crossings including Point Operating Equipment, track bed and sub structure, catenary and pantograph, …) are made more reliable thanks to novel designs and technologies, as well as simplified architectures. In particular, infrastructure is safe and resilient to degradation from climate change and extreme weather conditions, as well as to the use of longer, heavier, faster trains. Infrastructure is made compatible for high speed operation over 350km/h for passenger transport, as well as for high-speed freight,
	Enhanced capacity	Existing tracks have increased capacity thanks to new concepts for switches and crossings and self-steering vehicles. Better asset information allows for fewer failures and faster recovery after failures, increasing annual throughput and capacity. Less disruptive maintenance allows for higher utilisation of railway infrastructure. Stations are also designed to enable the higher throughput of passengers and freight generated by the system's overall increased capacity.
	Customer Experience	New "future station" design concepts integrating universal accessibility, and responding to evolving passenger needs in terms of information, technologies, multi-modality and security make it as easy as possible for passengers, including persons with reduced mobility, to transit busy stations and to switch modes.
Reduced system costs	Lower investments costs	The life-time cost of infrastructure assets, including tracks, switches and crossings , as well as tunnels and bridges is reduced thanks to new, more reliable subsystems, components and system architectures, using improved designs and materials that are self-adjusting, wear and weather resilient. This will result in lower installation costs, while lower degradation and longer asset life will lead to reduced maintenance needs and costs. Verification of projects for increasing capacity of existing and future infrastructure using simulation tools should decrease investment costs.

	Reduced operating costs	Better maintenance strategies and procedures allow for cost-efficient predictive maintenance, on the basis of risk-based or condition-based analytics, namely using more reliable sensor technology to detect real asset condition. Improved asset information and enhanced maintenance procedures, based on remote infrastructure condition monitoring and the introduction of automated, self-inspecting, adjusting and correcting concepts, lead to fewer defects and allow for less disruptive upgrades with less risk of operational unreliability. Energy efficiency is increased thanks reductions in thermal losses and in energy losses. The life-cycle cost of rolling stock (including authorisation) is reduced thanks to reduced diversity of infrastructure characteristics at the network-vehicle interface
	Externalities	Negative externalities such as noise and vibration can be effectively mitigated through the development of innovative designs and the use of innovative design and quieter components for infrastructure assets. Infrastructure waste is reduced thanks to improved asset life utilisation, namely of bridges and tunnels, tracks, switches and crossings and other infrastructure assets affected by wear and tear, allowing for fewer replacements, less waste and more recycling.
Enhanced interoperability	Respect and adaptation of TSIs	New infrastructure design takes into account interfaces with other sub-systems and uses generic designs and layouts and a holistic approach, thereby enabling rapid and cost-efficient construction and deployment as well as a reduction of network diversity. Adaption of TSIs to reflect scientific and technological developments.
	Removal of open-points	Remaining technical “open points” in existing target system specifications (TSIs) should be closed, in particular when it comes to the design requirement for tracks, including switches and crossings that are compatible with eddy current braking systems or the avoidance of the "ballast pick up" phenomenon, etc.
Simplified business processes	Improved standardisation	A common "predict and prevent" strategy using risk-based maintenance standards is validated and deployed. More standardized and reliable component technologies are introduced to allow lower maintenance costs and greater interoperability. Special attention is given to track quality parameters and the OCL/pantograph compatibility and interaction.

	Simplified certification and authorisation	Simplification of authorisation processes.

3.3.3 Indicative list of priority research and innovation activities

With a view to achieving the above objectives and outcomes, research and demonstration activities within IP3 should focus on the following areas and activities:

Area	Activities
New directions in switches and crossings	In the short to medium term, the focus should be on improving the operational performance of existing switches and crossings systems in terms of reliability and efficiency, by concentrating efforts on areas with the greatest potential for innovation, such as the point operating system, adjusting it to trains running at much higher speeds and with higher axle loads. Technology developed should make point operating equipment more robust and immune to extreme weather, and integrate mechanical, electrical and software components to deliver improved capabilities. Enhanced sensors, using new, quieter moving parts and materials, which can be embedded into the system (standardised to facilitate repair in case of faults) and which enable remote condition monitoring, as well as self-diagnosis and adjustment functions, namely thanks to the use of mechatronics, should be included. Longer term activities should look into the radical redesign of switch and crossing subsystems, concentrating on wheel rail interface and contact patch dynamics, kinematics of moving elements, improving motion control and cycle times, reducing noise and whole-life costs, while improving capacity, performance, availability, reliability and maintainability.
Innovative track design and materials	In the short to medium term, methods for measuring stress, degradation, stiffness, friction, defects, impacts from climatic changes, etc. on existing tracks need to be significantly enhanced to increase track lifetime and facilitate high-precision asset management. At the same time, damage prevention and mitigation strategies need to be enhanced, using integrated health monitoring systems and innovative methods for on-site rail manipulation. Technologies should also be developed for facilitating the operation of services between systems with gauge differences – speeding up the changeover process– and systems with different overhead contact lines accommodating

	different pantograph profiles. Longer term activities should seek to develop radically new concepts for track subsystems, as well as integrated track designs with standardised and modularised track components of limited complexity. New track solutions should encompass improved fastening and rail pad solutions, sleeper solutions and track foundation solutions, looking into the use of new materials, including elastomers, with a view to increasing durability, track stability, and safety, while reducing vibration and noise, whether running very high-speed trains or longer, heavier trains. Track solutions should also contribute to avoiding the “ballast pick up” phenomenon and be compatible with the use of eddy current braking systems (open points in the LOC&PAS TSI).
Cost effective Tunnel & Bridge solutions	Although many of Europe's 300,000 bridges and 3,500 km of railway tunnels[10] are close to or over the end of their planned service life, it would not be economically feasible or realistic to envisage their replacement on a large scale. Thus, an extension of the service life of bridges and tunnels should be a major priority. Activities should hence focus on developing faster and more accurate inspection methods and developing less disruptive repairing, strengthening and upgrading methods, using modern equipment and IT assessment tools. At the same time, new design concepts must maximise lifetime and minimise cost, while enabling the use of infrastructure by different segments, including for high speed rail.
Intelligent system maintenance	Intelligent maintenance systems, including predictive, risk-based or condition-based maintenance, should be built on cutting edge measurement and monitoring tools that provide static and dynamic data from all relevant components of the rail infrastructure, using train-borne, wayside and remote sensing measurement and monitoring systems, and based on secure, privacy and IPR-compliant open standards, to foster sharing of technical knowledge. Data should be analysed using cutting edge data mining and analytics, capable of advanced system and degradation modelling for whole-life cost estimates and with a view to introducing non destructive testing methods. Automation should be achieved for routine maintenance checks, as well as for

[10] Shift2Rail Technical Programme, December 2013

	repetitive tasks, such as track relaying, ballast renewal, tamping and alignment. Activities should also contribute to developing a standardisation process in the area of for infrastructure measuring, monitoring and maintenance.
Improved station concepts	Activities should focus on new, modular, inexpensive design concepts allowing for universal accessibility and multi-modality, taking into account the needs of an ageing society (e.g. step-free access), as well as new demands in terms of information, capacity, train/platform interfaces, functionality, space management, IT tools, lighting systems, and connections to other modes, including solutions for a safe universal level track crossing, etc. These design concepts could be implemented in new stations or retrofitted in existing stations and be adaptable to large and smaller stations. Improved station management concepts, based on a passenger-centred approach balancing passenger satisfaction, commercial interest, rail operation, heritage safekeeping and the environment, should also be examined and more efficient and privacy-friendly technologies and processes for station security should be developed.
Energy efficiency	New smart AC power supply system enabling parallel operation of substations feed from different phases, and load flow control for peaks and minimised losses. DC integrated power supply concepts, using wayside controlled equipment to reduce the weight of braking resistors and reduce distribution losses, double catenary feeding systems to reduce voltage drops along the railway, and controlled reversible substations for traction with energy storage modules and converters to provide complete flexibility to the energy network while allowing the implementation of infra smart grids. Smart metering for a railway distributed energy resource management system, in order to finely manage the different energy flows within the railway system as a whole. Smart energy storage systems are developed. All solutions will have to guarantee the quality of energy, solve EMC issues and adhere to specific railway standards and regulations.

3.4 IP4: IT Solutions for Attractive Railway Services

3.4.1 Challenge

To become more attractive, rail must respond to customer needs to support anytime, anywhere door to door intermodal journeys encompassing distinct modes of transportation. Rail must achieve interoperability with other transport modes and mobility services, with regions, cities and people engaged in social and economic activities, and with the key elements of the supply chains which can make Rail products and services available to those people. In order to achieve this, rail needs to take due advantage of the ever growing connectivity of people and objects, the availability of European GNSS based location, the advances in cloud computing, big, linked and open data and the propagation of Internet and social media. The step towards sharing data needs to be considered and progressively developed, in order to enable service developers to provide the connected travellers with the services they need and expect.

Customers are increasingly technology-savvy, and expect to get all relevant information at their fingertips in a few clicks, through a wide variety of data channels offering real time and personalised information. To achieve a full seamless multimodal travel experience, the customers must be able to easily plan and purchase door-to-door journeys. Ticketless or multi-application solutions that guarantee interconnectivity no matter where the traveller roams should become the norm.

Improved information technology, management and exploitation and cross-industry collaboration must help to provide passengers with smart and personalised services for journey information and ticket purchase together with entertainment and communication services. The development of truly multimodal infrastructures, providing for simple and seamless interchanges, including among different transport modes (i.e. urban and regional rail, air transport, road transport, cycling and walking) should make transfers easy, comfortable and reliable. For this reason, the timetables should be increasingly integrated across transport modes to allow better modal integration and minimise travellers' inconvenience. Station and staff information systems and personalised messaging help passengers throughout their journey, including the offer of alternative arrangements in the case of disruption. Technologies able to integrate of current and emerging standards shall be promoted through an interoperability framework.

In this respect, it will be essential to ensure that sufficient data is made available from all relevant actors in the railway sector to properly realise the benefits of these innovative IT services, which are key to the establishment of a fully functioning Single European Railway Area and Single European Transport System. It is also important to include the expertise of indirect distribution providers such as travel agencies and other travel intermediaries.

Within IP4, solutions from other relevant sectors must be analysed, best practice solutions will be adapted to the rail sector and standards will be considered. Equally, IP4 should draw on the results of industry initiatives or guidelines, such as Full Service Model for Rail, as well as EC funded projects such as ‘All Ways Travelling’, ‘IFM’, ‘EU Spirit’ etc.

3.4.2 Objectives

Objectives		Desired outcomes
Improved services and customer quality	Improved reliability	Increased and personalised passenger information on status of services will lead to an increased perception of reliability and reduce the negative impact of disruptions. It will improve door-to-door journey planning, the flexibility of services and provide for a better integration with other transport modes and availability of new add-on services, such as real-time re-accommodation. At the same time, enhanced information *from* passengers will enable a better planning of services, increased flexibility and overall reliability of the rail system.
	Enhanced capacity	Business analytics will provide all the tools to the operators to refine their offer and allocate capacity where and when necessary. At the same time, enhanced and integrated ticketing systems will enable a faster throughput helping to accommodate growing numbers of passengers from all customer segments.
	Customer Experience	Based on user's preferences, mobile travel companions will provide personalised journey information and whole journey integration, across multiple digital and distribution channels, in conjunction with other transport modes and service providers, including en-route assistance and specific guidance to PRM. Services are provided in a unified access point for all transport modes, regardless of their location, access method or format, including facilitated travel purchase for 'socially excluded' groups.
Reduced system costs	Lower investments costs	Enhanced information about real passenger routes will enable an improved calculation of the costs and benefits of future rail services, leading to a better allocation of rail investments. Sourcing and investment costs in advanced ICT solutions will be decreased by the opening of a competitive market, thanks to easier interoperability.
	Reduced operating costs	Integration of smart applications will enable transport operators to respond effectively and dynamically to passenger demand and help operators optimise their operations.
	Externalities	Improving the customer experience and improving modal integration leads to an increase of the attractiveness of collective mobility options and transport modes alternative to road. Information on the carbon footprint of journeys is provided to customers and enables them to make carbon-wise choices.

Enhanced interoperability	Respect and adaptation of TSIs	The TAP and TAF TSIs are fully respected. The activities under S2R may identify opportunities for the development and enhancement of TSI and other standards.
	Removal of open-points	Open specifications and access to the open interoperability framework will offer to any European travel industry player the tools to develop smart services for a seamless door to door travel experience (including with other modes of transport).
Simplified business processes	Improved standardisation	Harmonised terms and definitions of processes for the different services (planning, booking, ticketing, validation, re-accommodation, settlement, etc.) should be made. Media independent ticketing or travel entitlement data content should be enhanced to achieve complete interoperability between different modes.
	Simplified certification and authorisation	Setup of direct and indirect distributors and retailers is simplified by common and effective authorisation processes. Financial settlement between stakeholders is handled effectively by a harmonised approach at industry level

3.4.3 Indicative list of priority research and innovation activities

With a view to achieving the above objectives and outcomes, research and demonstration activities within IP4 should focus on the following areas and activities:

Area	Activities
Technical framework	Identify, formalise and document requirements and solution engineering specifications for interoperability using unambiguous semantic web technologies and open architecture and standard service interfaces. Unified and semantically consistent abstraction of the distribution information and the automated integration of existing data exchange specification (e.g. the mandatory Commission Regulation TAP-TSI, and commercial solutions / voluntary standards such as NeTEx, SIRI, RailXML, GTFS, etc.) enable decentralised deployment (to local rail travel services companies, internet service providers, etc.), decentralised management (whereby providers and consumers of transportation services can publish their specification-compliant services). At the same time, a business analytics platform should provide engineering specifications for architecture, data model & services design and develop modules for travel & transport big data development, core and support services development, as well as integration tests. All the developments should

	be modular, based on open specifications.
Customer experience applications	Develop secured customer experience applications reflecting each "travel environment" including customer preferences, itineraries, preselected payment means, and giving access to additional services such as en-route assistance, guidance to PRMs or passenger right information, etc. The developed solutions should also provide real-time information on relevant events that could affect the traveller's journey and match these with the traveller's preferences and door-to-door itineraries. All the developments should be modular, based on open specifications.
Multimodal travel services	Develop one-stop-shop solutions and applications for multi-modal shopping and ticketing enabling integrated door-to-door, multi-modal itineraries in answer to a traveler mobility query. All the developments should be modular, based on open specifications.

3.5 IP5: Technologies for Sustainable and Attractive European Rail Freight

3.5.1 Challenge

Although the rail freight markets within the EU have been open for a number of years, the modal share of intra-EU rail freight transport has slightly declined in the past decade. The industry’s stagnation can partly be explained by the existence of legal barriers restricting competition (including the track access regime, taxation, etc.), but also by problems of operational and technical nature, which impact the overall capacity and performance of the sector.

The cost competitiveness and the reliability of freight services need to be considerably improved if the sector is to meet the ambitious objectives that were set in the Transport White Paper in terms of developing rail freight; almost doubling the use of rail freight compared to 2005, achieving a shift of 30% of road freight over 300 km to modes such as rail or waterborne transport by 2030, and more than 50% by 2050. Rail freight must be in a position to offer a cost-effective, attractive service to shippers that helps to take freight away from the already-congested road network.

The challenge is two-fold:

- To acquire a new service-oriented profile for rail freight services based on excellence in on-time delivery at competitive prices, interweaving its operations with other transport modes, addressing the needs of the clientele among others by incorporating innovative value-added services.
- To increase productivity, by addressing current operational and system weaknesses and limitations, including interoperability issues, and finding cost-effective solutions to these problems, including optimisation of existing infrastructure and fostering technology transfer from other sectors into rail freight.

In order to secure and strengthen rail's market position in current markets while at the same time enabling it to (re-)enter into new/lost market segments, investments in research and development must target the market segments where the progress is reachable in the short term and market segments with an important growth potential in terms of transport volumes and revenue potential.

Different market segments with specific technical and operational characteristics can be identified. The first segment is the intermodal segment, which mainly relies on the use of containers / trailer trains. Continued growth can be expected in the intermodal segment. Reliability, service characteristics and cost competitiveness in this segment can progress significantly with an increase in train length, better length utilisation, innovative rolling stock features for value-added services, progress in the terminal operations – i.e. through synchronisation with train movements on the network and with the road mode in pre- and post-haulage and improved real-time information to customers and better data exchange between involved parties in the intermodal transport chain.

A second market segment is the wagon load / block train activity segment, which relies on the use of specific freight wagons. This segment has significantly declined in the past years and its significant growth potential can only be fully exploited if a step change is made in terms of service quality and reliability. Revitalising the small volume market would require an industrialisation of the production methods. Solutions such as automated coupling and decoupling, tagging of all wagons with RFID tags automatically readable provide a huge potential to speed up and reduce costs in train formation and to improve the overall performance of wagonload services. Enabling technology is needed to realise economies of scale on the long-distance legs of a wagonload system – e.g. through train-coupling and -sharing – which must be combined with new ways to carry out last-mile operations. Better integration of wagonload resources in information flows is necessary to be successful. The prospects of integrated production of wagonload and intermodal services must be exploited as well.

What's more, given that rail freight has an advantage over other modes when it comes to the transport of dangerous goods, identifying and developing innovative solutions to make the carriage of dangerous goods by rail the obvious number one choice is also essential.

Taking into account the fierce competition with road transport, it is important that future rail freight solutions are developed to optimise the overall transport time; this include a reduction of the handling and set up time at marshalling yards and in terminals and an overall increase of the average speed for rail freight operations (including for certain market segments even an increase of the top speed). All innovation activities should also ensure that rail freight is able to better operate in conjunction with passenger traffic in order to maximise the utilisation of the existing network.

Furthermore, the freight sector should build on best practice from the passenger sector and from other modes, in terms of information, planning and monitoring systems.

Improving the rail freight performance also implies addressing the critical issues of rail noise and the continued improvement of its environmental performance, e.g. through electrification / hybrid propulsion.

3.5.2 Objectives

Objectives		Desired outcomes
Improved services and customer quality	Improved reliability	Reliability of vehicles is increased thanks to the use of new technologies and components for key systems and sub-systems. Handling time in intermodal terminals and train formation times in freight and marshalling yards is reduced, through efficient coupling, etc. The coordination and negotiation of competitive international freight paths and transport capacity is improved in terms of time and costs. New multimodal information, planning and management systems provide real-time information to shippers, forwarders and train operators.

	Enhanced capacity	Freight wagon design is improved to increase wagon capacity and average speed. New generations of locomotives and braking systems enable the operation of longer (up to 1500m) and heavier trains. New terminal management systems include optimal modules for handling and storage in terminals and better coordination of traffic management.
	Customer Experience	Integrated information and planning systems, which cover the whole logistics and transport chains, are implemented to support shippers, forwarders and transport operators. Real-time data provide ETA information and a new ETA calculation is developed in an integrated manner for all modes/parts of the transport chain. Innovative freight wagon concepts provide new value-added service features, such as electric power supply/connection. Dual / hybrid propulsion systems, including alternative refit and hybridisation concepts for existing areas of application, based on life-cycle costs, flexibility, safety and infrastructure requirements.
Reduced system costs	Lower investments costs	A larger volume or a higher payload improves the utilisation of the wagon and results in the relative reduction in the needed number of vehicles of a given capacity and generates a higher return on investments for the operations. The development of hybrid propulsions systems provides new opportunities for operators to achieve a more versatile locomotive fleet. Higher level of standardisation contributes to lower investment and maintenance costs.
	Reduced operating costs	Operating costs are reduced through more versatile locomotives and freight wagons, industrialisation of processes, higher levels of automation and higher energy-efficiency. The operation of longer trains and dual power traction in last-mile operations reduces the operating costs and increases flexibility. Better and more standardised on-line monitoring provide accurate data on the actual condition of the train to optimise vehicle maintenance and operation control. Track friendly vehicles with better running properties lead to a reduction of the rolling stock and infrastructure maintenance effort.
	Externalities	A modern wagon design is developed for more energy-efficient and quieter trains with an improved payload-deadweight ratio. Braking systems are improved to reduce noise. Electrification of rail freight and the development of next generation/hybrid propulsion results in a reduction of air pollution from diesel locomotives and noise in last-mile operations and in terminals..

Enhanced interoperability	Respect and adaptation of TSIs	Transport documents in the intermodal transport chain are harmonised, interfaces are developed with the TAF TSI standard, Information on the movement of trains is synchronised with terminal operation.
	Removal of open-points	Interoperability with other modes is improved through better exchange of information with other transport modes, in particular road transport, and with terminals as the interfaces become compatible between the modes.
Simplified business processes	Improved standardisation	Data on train conditions are integrated in standard diagnostic systems. New components of freight wagon designs are standardised. Systems and procedures for automation of train formation processes and operation of longer/heavier trains are standardised. Transport documents in intermodal transport chains are harmonised. Common standard interface for driver assistance systems.
	Simplified certification and authorisation	Simplification of authorisation processes.

3.5.3 Indicative list of priority research and innovation activities

With a view to achieving the above objectives and outcomes, research and demonstration activities within IP5 should focus on the following areas and activities:

Area	Activities
Implementation Strategies and Business Analytics	Socio-economic cost-benefit analysis of innovative solutions and implementation strategies Operational solutions for European-wide migration to innovative solutions with major system impact Development of multi-partner business models for migration to innovative solutions in rail freight
Freight Electrification, Brake and Telematics	“By wire” Communication and Electro-Pneumatic Brake System Electric power supply/connection on freight wagons, including interface to intermodal loading units (e.g. to reefer units), train integrity function and control Freight wagon/train and goods status monitoring and data

	management/supervision, tracking, condition based maintenance Advanced condition monitoring, localization and diagnosis of locomotive and freight wagons in operation Friction Brake Technologies, Disk Brakes, Wheel Slide Protection for Freight Wagons Brake Module Kit, interoperable UIC-GOST Control Valve Automatic Couplers, smart technologies for wagons coupling/uncoupling in terminals and marshalling yards Automated Train Formation, automated brake test definition and harmonised braking regimes On-board automatic solution for freight track gauge change
Access and Operation	Collection and processing of combinations of different transport chains for individual transport units (“door to door planning system”) Combination of border crossing train path allocation and slot management, including "code-sharing" of train paths, e.g. by long trains Provision of real time data Improvement of the interoperability and maintained safety, reducing barriers to interoperability and preventing safety from being misused for discrimination of RUs Promotion of market opening Creation of incentives for product innovation and service quality networks. Vitalisation of the wagon load market Sharing of train and marshalling yards capacity
Wagon design	Wagon design including new bogie solutions, running gear for higher speed, lower noise, running stability, lower wear and tear, intelligent safety sensors, disc brakes, power-pack and generator aiming at reduced overall costs/high safety. Asset intelligence, i.e. monitoring of vehicle status component condition for predictive maintenance Pocket wagon frame construction for higher speed, dynamic stability, de ice and snow protection and safety systems. Platform wagon frame for high speed, stability and stiffness to wagon and also safety solutions especially for dangerous goods transports.

	Measures for low-noise wagons and low-vibration wagons; reduction of dynamic forces in the wheel/rail-interface.
Novel Terminal, Hubs, Marshalling yards, Sidings	Support the MIX TRAINS implementation (flexible, multiple stops services with versatile and intelligent wagons, …) Innovative systems for improved data gathering, steering, operation and coordination. Endorse the Management Orchestration (quick-stop, network and dynamic path allocation, integrated node-path management, dynamic planning) Minimise operations (shunting through fast trains, automated couplers, reduction of handling time, automation in damage recognition, brakes check) Hybridisation of Shunting Fleet, including retrofitting
New Freight Propulsion Concepts	Greater Flexibility and Interoperability and resilience (ability to operate under all climatic conditions in Europe) Reduction on the operation costs (€/ton x km) through the operation of Longer Trains and Dual Power (master-slave operations) New power technologies, sustainable and environmentally friendly solutions, including battery solutions. Compatibility to New Generation of Wagons (interaction with research and innovation area – Freight Electrification, Brake and Telematics of IP5)
Sustainable rail transport of dangerous goods	New wagon and transport equipment/packaging design, including technologies to prevent train accidents and incidents and reduce impact of such accidents and incidents ICT and systems to collect and distribute data related to transport of dangerous goods by rail, including telematics applications based on TAF-TSI, with a view to monitor traffic and movement of dangerous goods and facilitate intervention of emergency services in case of incidents and accidents
Long-term vision for an autonomous rail freight system	Design concept of a rail freight system based on autonomous movement of intelligent wagons and its integration in intermodal supply chains

3.6 *Cross-cutting themes and activities*

In addition to the five Innovation Programmes, the work of Shift2Rail will also be structured around five cross-cutting themes that are of relevance to each of the different sub-systems and take into account the interactions between these sub-systems.

These cross-cutting activities will ensure that the R&I activities within the different Innovation Programmes are closely aligned in terms of their objectives and their requirements, as well as the methodologies for evaluation and assessment of impacts. These activities include elements already taken into account in the different Innovation Programmes that require horizontal coordination (such as energy and noise management) and additional research that will be necessary to complement the technical work of Shift2Rail.

3.6.1 Long-term needs and socio-economic research

Innovative foresight approaches that can stimulate a new strategic thinking about the rail system of the future are required. They should enable identification and better understanding of key trends, such as urbanisation, demographic changes, ageing of society, hyper-connectivity, etc., that might affect rail services in different segments and how they can better satisfy the complex needs of a rapidly evolving society.

Indeed, rail transport can only compete with other modes and attract more passengers and freight in the future if passenger and freight services fulfil the needs of the end users in terms of efficiency, affordability, quality, comfort, accessibility, punctuality and reliability, flexibility, information and value for money. A common methodology and tools to better understand the mobility behaviour of users and predict customer needs and reactions to innovative mobility measures are required. It will also be important to identify supporting measures that may be required in order to ensure that the full potential of the technical work conducted in the IPs is achieved in terms of passenger perception and the resulting modal shift.

At the same time, the business-led needs of the railway undertakings, as the main customers of the rail supply industry, also have to be considered when developing the railway transport system. In particular, economic research will help to develop customer-oriented business models of the future, guaranteeing optimal sharing of responsibilities in operations, or identifying and developing new high-value market segments, such as the use of high speed technology for mass transportation, flexible logistics solutions in freight, transport of dangerous goods, etc.

The future functional requirements for the development of the rail system should therefore be based on a systematic analysis of both business needs and user needs, as well as on a suitable methodology for assessing the costs and benefits of different innovations.

Indeed, in order to achieve market uptake in the regulatory framework, a precondition is that not only the technical work of Shift2Rail be compatible with the system specifications for the Single European Rail Area (TSIs) but also that there is a common approach to economic and safety analysis in the entire sector (incl. suppliers, end users, regulatory authorities, etc.).

Yet, there is currently no common methodology for evaluating the economic, safety and environmental impacts, costs and benefits of the different R&I actions and their contribution to the Shift2Rail objectives. Therefore, one of the tasks of the S2R JU will be to develop such a methodology demonstrating the qualitative contribution of each TD to the objective that applies to it with a view to delivering the most viable technical solutions and the optimal level of technical harmonisation. Where relevant, this method could be used to update the level of priority of the Joint Undertaking's projects or to identify possible gaps to close or when some requirements become obsolete due to the introduction of innovative technologies.

3.6.2 Smart materials and processes

Market uptake of a new technology cannot happen unless it is possible to verify and authorise it. Shift2Rail must address the issue of verification, testing and certification.

In particular, activities will focus on eliminating on-track testing, which is an expensive and wholly inefficient means of verifying conformity. It is impossible to simulate all situations in a short series of tests on one route and the results are influenced by factors out with the verification bodies control (e.g. the weather). It is also extremely expensive and difficult to organise (e.g. track access issues). The development of smart processes for the reduction of on-track testing could lead to a simplification of authorisation processes while still guaranteeing a high level of safety. Shift2Rail research activities should also seek to benefit from knowledge-exchange with aeronautic and road sectors for visual inspection (e.g. crack-checks), magnetic particle inspection (e.g. to check integrity of ferromagnetic parts of assets), radiography, ultrasonic (active) (e.g. to locate defects in all types of materials), holography (which could be applicable to preventive maintenance).

Certification activities will also focus on integrating new materials and innovative industrial processes from other sectors. Indeed, new materials such as composites, light metallic alloys or nanomaterials could support the enhancement of rolling stock and rail infrastructure by making it lighter, more resistant or weather resilient for example. However, the introduction of such materials poses challenges in terms of current maintenance and certification processes that will require an evolution in the existing regulatory framework. This question must be examined in order for the sector to understand which changes, if any, need to be made.

As such, knowledge-exchange with other industries and sectors could and should occur in the adoption of innovative industrial processes. There is a unique opportunity for Shift2Rail to adapt key materials from the aerospace and road sectors but also from the marine or energy turbines industries, or from material technology suppliers. Mechatronic science and its various applications in the road and aviation sectors also offer huge opportunities in terms of reducing maintenance costs and enabling automation, energy savings and noise reduction. There is also a rich pipeline of innovations in materials and processes—from nanomaterial to 3-D printing to advanced robotics—promises to create fresh demand and drive further productivity gains across manufacturing industries and geographies. For instance, innovations such as 3-D printing could offer a long-term solution for the replacement of spare parts in the rail sector. Shift2Rail should also take up best practices for integrating Big Data analytics into existing business processes and workflows and define relevant deployment scenarios for an EU wide implementation of IT applications, taking into account the necessary transition phase.

3.6.3 System integration, safety and interoperability

Shift2Rail focuses on innovation that will only take place if R&D, industrialisation, and a wide market uptake are combined. Therefore the solutions that will be developed will have to be highly interoperable and provide the required level of standardisation for a long-term, easy and cost-efficient, operation and maintainability of the railway system.

The European Railway Area is a system shared between many stakeholders each of them responsible for their part of the system. Common system specifications for the Single European Rail Area have been defined by the TSIs. Shift2Rail activities should not only ensure that TSIs are fulfilled, but also aim at, when possible, contributing to the closing of remaining "open points" in today's target system specifications. S2R should equally ensure that its outputs enable TSIs to be adapted, when necessary, to take into account the development and the introduction of new technologies. In this respect, continuous communication between the S2R Joint Undertaking and the European Railway Agency will be essential.

Furthermore, in order to ensure that the optimal level of technical harmonisation can be defined for the future target rail system, including the long-term maintainability of the railway system, there is a need for stable interfaces among the sub-systems of the railway system architecture. Shift2Rail should therefore use a system architecture for each of the sub-systems developed by Shift2Rail, taking account of existing ENs, and, where useful, define at the relevant level the minimum set of interfaces that could ultimately lead to a "plug & play" approach. The results of Shift2Rail shall include the physical, functional and technical specifications for the selected interfaces, in order to promote the design and market entry of competitive solutions which are in line with the objectives of ensuring interoperability in the rail system but that do not restrict the development of innovative solutions that meet the functional requirements. Shift2Rail should also take account of EU standards from the inception (or propose for modification/ creation), considering the requirements of the users all along the R&D phase based on a common EU system architecture/ approach, that will use the concept of modularity and harmonisation of functions / interfaces each time it is possible represents the most viable solution/the optimal level of harmonisation.

In addition common EU operational rules harmonised across all EU networks and EU authorisation/ certification methods are equally important for the delivery of cost-effective and quality products that can be easily produced and maintained in a timely manner in Europe. For this reason, the definition of a target operations concept, defining the optimal level of harmonisation of operation and traffic management is equally crucial. Being based on a system approach including all relevant stakeholders of the sector, the research undertaken by Shift2Rail should also reflect this issue and seek for appropriate cooperation between the various stakeholders. At every stage the research must take full account of the roles and responsibilities allocated by regulation to RUs and IMs and functionalities allocated by the TSIs to vehicles and networks.

At the moment traffic management is an unspecified part of the Control Command Signalling system, with each country adopting its own systems. Shift2Rail needs to contribute to developing an integrated operations concept that allows for harmonisation across Europe. Integrated mobility management must be smart and based on a real-time seamless access (without duplication) to heterogeneous openly available railway data sources (signalling data, maintenance plans, environmental conditions, fleet status, passengers requests and needs; etc.) with a view to enabling all rail stakeholders to measure their performance and optimise their operations and planning, and ultimately the service they offer to the end users (meaning travellers and freight customers). It will also provide a seamless exchange of information between fixed and mobile services in different transport modes.

A common horizontal approach to IT architecture is also needed so that a consistent approach is taken to IT on issues common to the various projects developed as part of the 5 IPs. Previous EU--funded projects should be taken into account to identify which IT interfaces should / could be harmonised (both within rail vehicles and between rail vehicles and fixed equipment).

Maintaining and improving system safety has always been recognised as an essential element of rail research and innovation projects in the past and providing the optimal level of safety should remain one of the key objectives of Shift2Rail. S2R activities should be able to trigger safety improvements through technology and to check the safety improvements achieved with the combinations (into a system) of all technological developments in the Joint Undertaking. Based on a common approach on safety and risk, Shift2Rail will be able to identify when innovation can unlock safety barriers and when safety rules become obsolete and need to be revisited. In addition to the safety improvements that will be delivered through the technology developments, Shift2Rail should also study and review elements such as resilience, human and organisational factors, risk acceptance criteria, etc.

3.6.4 Energy and sustainability

The environmental performance of the rail sector is an important element to be taken into account, which can be addressed through different angles: the improvement of energy efficiency (thus leading to CO2 reductions), a better energy mix (electrification and use of renewables) and the solutions to address other externalities such as noise. Energy, and consequently CO2, savings should cover the entire railway system including operation, infrastructure, rolling stock, sub-systems (such as traction and running gear for example) and components. These savings will improve the already excellent environmental balance of rail while reducing the cost of energy, thereby making train travel more affordable and thus promoting modal shift to rail.

All potential new solutions will have to be monitored and evaluated to achieve optimal energy-efficient technical solutions across all system platform demonstrations (given that urban, regional, high speed and freight segments have different characteristics and constraints that could lead to different technical solutions for energy savings in the different segments), and taking into account technical risks and investment costs for all stakeholders. Methods for quantification of energy and CO_2 savings at EU level based on different levels of investment should also be developed.

Knowledge from the energy sector in relation to standard power supply systems, smart grid design and integration of renewable energy sources such as solar, wind, fuel cell technologies and hybrid propulsion should be widely used in Shift2Rail energy efficiency research activities with a view to better managing future higher overall levels of energy consumption and intelligently respond to the behaviour and actions of all electric power producers/users in the railway system.

Noise and Vibration (N&V) is one of the major concerns that needs to be addressed with a view to meeting the EU's ambitious goals of increasing the capacity and competitiveness of rail, particularly in the freight segment. On some lines, the capacity has been restricted because of regulations governing N&V exposure to limit disturbance to nearby residents. In such cases, there is a clear economic case to reduce the noise emissions of passing trains, to create tangible benefits and allow more train services to pass, thus increasing traffic capacity on the railway. The overall impact on future railway systems will be important to consider, since only a system approach taking into account the combination of low noise rolling stock and low noise infrastructure will assure the competiveness of a green high capacity European railway system.

For interior N&V, the comfort and attractiveness for passengers as well as the working conditions for on-board staff is a complex challenge. It will be crucial to offer an attractive product, in which the N&V performance is one important feature, to achieve the goals of Shift^{2}Rail to revitalise the railway sector and considerably increase the market share compared to other transport modes. Activities should also focus on further enhancing methods for predicting overall noise performance on a system level, with a proper ranking of each contributing source (with separation of rolling stock noise from track noise during vehicle pass-by), so as to include different combinations of entire vehicles and infrastructure. This will also clarify what future targets can be possible for the TSI (Technical Specification for Interoperability) on Noise and goals that the market might require.

3.6.5 Human capital

The performance of the rail system depends as much upon humans as machines. Yet this dimension is frequently neglected. The concept of the continuously open railway depends on organised, reliable, well trained and professional people who enable the efficient operation of the system.

Lifelong learning is an expectation within the industry and learning programmes need to take full account of the implications of technology-driven changes. Virtual learning environments and simulations should be used to rehearse responses to both routine work and unplanned situations. All Research and Innovation activities in Shift2Rail should include a human factor element and ensure that these issues are properly addressed in designing the projects and using the outputs. Other issues to be looked at are driver behaviour when working with more than one set of operating rules, including safety and operation, training, etc.

Cross-cutting research in this field should include forecasts of the skills that railway will need and analysis of gaps in skills; coherent standards for collaboration, improved risk management, development of tools to ensure increased flexibility of railway staff; development of a new generation of decision support tools, including timetabling and maintenance schedule planning.

Knowledge-transfer from other sectors is a key aspect for the future of rail transport and strategic relationships with other sectors are required to understand the skills that are required and ensure synergies with regard to skills that are not railway specific.

4 Monitoring progress and impact

The progress and performance of all R&I activities within the S2R Joint Undertaking will be closely monitored in accordance with Article 3(4) of the S2R Regulation. It is the task of the S2R Joint Undertaking to ensure the effectiveness and efficiency of rail research and innovation activities and follow progress towards the achievement of the S2R Joint Undertaking objectives through adequate monitoring and evaluation processes.

The Joint Undertaking will produce every year an annual activity report on the progress made by the S2R Joint Undertaking. This report will include, inter alia, information on:

- Research, innovation and other actions carried out and the corresponding funding, including a breakdown by participant type, including SMEs, and by country;
- The progress towards the achievement of the S2R objectives and proposals for further necessary work to achieve these objectives.

In order to ensure that the results of all R&I activities contribute to the general objectives of the Shift2Rail initiative and meet the expectations regarding the Shift2Rail specific targets (e.g. 50% reduction of the life-cycle cost, 100% capacity increase, 50% increase in the reliability and punctuality) technical monitoring as well as socio-economic impact assessment is needed.

Key Performance Indicators (KPI) will be used to demonstrate the improvements resulting from innovative technologies and solutions developed in Shift2Rail.

The monitoring of progress and Impact Assessment of the R&I activities in Shift2Rail will be carried out with the help of quantitative and qualitative Key Performance Indicators at three levels:

- **KPI Level 1**: monitor the progress in meeting the TD related objectives and impact of the R&I developments and Technology Demonstrators of a specific topic or priority.
- **KPI Level 2**: monitor the progress of S2R Joint Undertaking with regard to the specific targets of the S2R Joint Undertaking.
- **KPI Level 3**: address the contribution to the accomplishment of the overall strategic objectives of the S2R Joint Undertaking (e.g. achievement of the Single European Railway Area, development of a strong and globally competitive European rail industry, etc.)

To enable this, a core task of the Joint Undertaking will be to develop a suitable methodology for gathering and exploiting the necessary data to measure these indicators and monitor the contribution of Shift2Rail to their progress.

The model developed by the JU will seek to assess the optimal combination of technology developments to achieve these KPIs, bearing in mind that the relations between the KPIs are complex and that advances in one area could impact negatively on other indicators. This means that the progress and impact of all S2R activities should be assessed first on the level of Technology Demonstrators, then on the level of Integrated Technology Demonstrators (ITDs), and then at system level for each of the 4 market segments: high-speed passenger transport, regional passenger transport, urban/suburban passenger transport, freight transport.